

On instituting a comparison between the results now communicated and those formerly published for the triplet of zinc double sulphates, it is found that the replacement of sulphur by selenium is generally accompanied by a change in the morphological and physical constants similar to that which accompanies the replacement of one alkali metal by another of higher atomic weight. The changes due to the latter chemical change are often smaller in the selenate series than in the sulphate series, the greater weight of the initial molecule appearing to offer greater resistance to change. The intermediate character of the constants of the rubidium salt is, however, the invariable rule in both cases.

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“An Experimental Inquiry into Scurvy.”\* By FREDERICK G. JACKSON and VAUGHAN HARLEY, M.D. Communicated by LORD LISTER, P.R.S. Received February 15,—Read March 1, 1900.

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The view that scurvy is caused by the want of fresh vegetables or lime juice, which has been the teaching of physicians and scientists in past years, would appear to require modification.

In the early part of this century, through the efforts largely of Lind, the better feeding of sailors led to the gradual disappearance of scurvy in the naval service, and from this and other observed facts it was conceived that the disease developed whenever individuals did not receive a sufficient quantity of fresh vegetables, or some substitute, such as lime juice, in the diet.

Garrod held that the cause of scurvy was a deficiency of potassium salts, while others believed the essential factor to be the absence of organic salts, which are present in fruits and vegetables.

Ralfe believed the absence from the food of malates, citrates, and lactates reduced the alkalinity of the blood, and thus was the cause of scurvy. It was proved, however, by analysis that the alkalinity of the blood was not diminished, and the majority of evidence showed no diminution in the quantity of potash salts in the scorbutic blood, so that these explanations had to be abandoned.

Neale, in an article on “Scurvy in the Arctic Regions,” published in the ‘Practitioner,’ 1896, stated that “scurvy is a disease due to want of proper ventilation and want of proper blood nourishment; in fact, scurvy begins with anæmia, and its great antidote is fresh blood.” He consequently did not consider that fresh vegetables were of such

\* Towards the expenses of this research a grant was received from the Royal Society.

prominent importance in the warding off of scurvy as the general teaching up to the present has led us to believe. These remarks of his were drawn from practical experience in the Arctic regions, as will be later mentioned.

It is to the sojourners in the Arctic and Antarctic climes that scurvy nowadays is of such overwhelming importance, although in some lands nearer home it is still rife, and occasional cases even now occur in our marine services. Credit, as has been already stated, has been given to the use of lime juice in the Royal Navy and the Merchant Service for the great reduction of scurvy on board ship, but, as this research will presently show, this conclusion is probably without justification.

In the Nares Polar Expedition the crews of both the "Alert" and the "Discovery" suffered greatly from this affliction, although lime juice was taken daily by all hands when on board. When on the sledging expeditions, in consequence of the necessities of such a condition of travel, only a small quantity of lime juice was carried, yet an outbreak of scurvy occurred, not only amongst the sledging parties, but also amongst the men that remained on board ship and continued to take the prescribed allowance of lime juice daily.

On the other hand Mr. Leigh Smith's party, with its medical officer, Dr. Neale, after the loss of their ship the "Eira," spent nine months, including a winter, upon Franz Josef Land, in the severest, and, necessarily, the most unsanitary, conditions imaginable. They had no lime juice whatever; however, they almost entirely lived upon freshly killed meat and frozen blood, and no case of scurvy occurred amongst them.

On comparing these two examples we see that in the case of a body of picked men, well housed, well cared for, and with all possible means for procuring health adopted by those in command, taking the prescribed quantity of lime juice daily (except in the case of the sledge crews when absent from the ship for a few weeks) but who lived almost entirely on preserved meat, we have universal scurvy; while, on the other hand, we have a party who had not been selected on account of physical fitness, who were cast upon the desolate shores of Franz Josef Land, and with only the bare necessities of existence, passed through nine months of their life there under conditions of considerable privation and hardship, and in circumstances which would hardly meet with the approval of any sanitary inspector. They had no lime juice, but lived on freshly killed bear and walrus meat, and no symptoms of scurvy appeared amongst them.

No less striking results were obtained by Dr. Nansen and Lieutenant Johansen. These two individuals, after they left the "Fram," had to spend nine months, including the winter of 1895 and 1896, on Frederick Jackson Island. They were forced to live in a rudely constructed hut,

without any changes of clothing, and no possibilities of washing, so that their sanitary conditions were not only of the roughest description, but the most unsuitable possible for health, and during the whole of this time they had no fresh vegetables whatsoever, and not even any lime juice. The only food they were able to use was fresh walrus or bear's meat, which had been preserved simply by the cold. During this entire period they ate no salted or tinned meats, and we can presume that the bear and walrus meat, as it would freeze almost immediately on being killed, would remain perfectly fresh.

In consequence apparently of the purely fresh meat, and in spite of the most unsanitary conditions, Nansen and Johansen passed the whole winter almost constantly in the dark, without exercise, and yet showed no symptoms of scurvy whatsoever. In fact, the results with these two individuals show that Neale's view, who had laid special stress on the want of proper ventilation as one of the causes of scurvy, was not realised, for the ventilation of their hut must have been extremely bad, as they describe the soot from their blubber lamps being deposited everywhere.

Before commenting on this a few more examples in reference to this important subject may well be given.

One of us (F. G. J.), when living amongst the Samoyads on Waigatz Island, and the Bolshaia Zemelskija Tundra in 1893 and 1894, observed some striking facts as to the cause of scurvy.

Amongst those of the Samoyads who invariably winter upon Waigatz, who never take vegetables nor know of lime juice, scurvy is unknown. They, however, live entirely upon fresh reindeer meat. On the other hand amongst those Samoyads, who in the autumn migrate south with the Russian peasant traders from the neighbourhood of Yugor Straits, and live in common with them in the districts adjoining the large rivers in North-East Russia upon salted fish—the chief winter food there until the following May—scurvy is prevalent. That this fish is invariably tainted can be testified to from personal experience.

In 1893, when at Kharborova, a Samoyad settlement on the Yugor Straits, a remarkable case pointing to the cause of scurvy came under his notice. Six Russian priests, whose religion forbade them to eat reindeer or other such meats, but allowed salted fish, were left in a hut by Siberiakoff, the wealthy mine-owner, to pass the winter, a year or two prior to F. G. J.'s visit. A small Russian peasant boy—whom he conversed with—was left to wait upon them. The priests lived almost exclusively on tea, bread, and salted fish; the boy lived upon similar food, except that instead of the salted fish he ate fresh reindeer meat. None of them had any vegetables. In the following May, when the Samoyads and peasant traders returned, they found that all the six priests had died of scurvy, whereas the little boy, who had lived upon

fresh meat and had not eaten salted fish, was alive and well, and had buried all his late masters in the snow, he being the only living being in Kharborova in the spring.

In the experiences collected by one of us—F. G. J., during his late expedition to Franz Josef Land in 1894, 1895, 1896, and 1897—we have two parties to consider: that of the crew of the “Windward,” who spent the winter of 1894 and 1895 there, no individual of which ever failed to take his prescribed ounce of lime juice daily, and yet scurvy broke out, causing at least one death; and on the other hand the land party on shore who took no lime juice, except two or three of them, who used it as a refreshing drink during the first few months, after which none was used. During the three years that they passed in Franz Josef Land none of them suffered from any symptoms of scurvy. The difference between these parties was principally, if not entirely, due to the meat. The “Windward” party used largely tinned and salted meat; while, on the other hand, the land party principally lived on bear’s meat, and when tinned meat was employed, it passed a severe scrutiny in order that as far as possible it might be not even tainted.

From these and other facts it would appear that neither lime juice nor fresh vegetables either prevent scurvy or cure it, and it is not the absence of this which is the cause of the disease, but that scurvy is a disease produced through the eating of *tainted food*.

The view that scurvy is essentially due to poisoning by the ptomaines of tainted animal food was first propounded by Professor Torup, of Christiania, and it would appear from the foregoing evidence that such is the case, for in all the cases above mentioned where any scurvy occurred the men had lived on tinned meats or salted foods.

Confirming this view, Dr. George M. Robertson, of the Perth District Asylum, relates a case of a woman who had become an inmate chiefly owing to her malady having taken the form of eating filth from pigs’ troughs. On arrival in the asylum she was found to be suffering from spongy ulcerated gums—in fact, from “land scurvy,” and ultimately all the teeth, except the canines, fell out.

In the many instances of scurvy that we have investigated, in no single case have the circumstances rendered inadmissible, or even improbable, the theory that this disease is due to ptomaine poisoning. Before giving to lime juice the credit of having practically swept away scurvy from the naval and marine services, it is necessary to remember that other causes have at the same time been at work to promote health, such as improved sanitation, better quarters for the men, shorter voyages through the enormous increase in the use of steam, and above all *better food*.

The evidence so far shown, in which men have unwillingly experimented on the effects of ptomaine poisoning, proves that scurvy is

produced by the eating of tainted meat, and not by the want of fresh vegetables. In order to confirm or negative this view, it was decided to carry out some experiments in this country. After careful consideration, it was concluded that the most suitable animals for such experiments would be monkeys, since they are mostly nearly allied to man. Monkeys are not naturally carnivorous, and therefore it would be necessary to give the meat mixed with food that would not possess any alleged anti-scorbutic properties; and for this purpose it was decided to feed the monkeys on boiled rice and maize. In order to keep the standard of meat as nearly as possible always the same, a certain brand of tinned Australian beef was employed.

Daily the rice was well boiled, and, after becoming thoroughly softened, 50 grammes of meat was added to each portion of rice for the various monkeys. It was then well stirred and gently heated; by this means the meat got well mixed with the rice, and, although the monkeys might reject some of the larger lumps of meat, a considerable portion of it was eaten. At the same time any soluble ptomaines would be absorbed by the rice, and thus eaten by the monkeys. To this mixture daily was added a certain amount of maize. The results can be best described by dividing the experiments into three groups.

*First Group.*—The monkeys in this group were given daily, together with their boiled rice, 50 grammes of meat from a *freshly* opened tin, together with maize.

*Second Group.*—The monkeys in this group were given the same quantities of meat as in the previous group, but from tins which had been opened for a few days, and had stood in the laboratory. The meat in these was not what one would call bad, although it had a distinctly sour smell. Rice and maize as before.

*Third Group.*—The monkeys in this series were given exactly the same diet as was employed in the second group, except that each monkey received daily either an apple or a banana.

We have found in these three groups three conditions, so far as diet is concerned, which ought to yield definite results in reference to the subject of ptomaine poisoning,

In order that the general surroundings of the monkeys should be as nearly as possible the same, and that each should be properly observed, every monkey was kept in a separate cage of similar construction, so that the fæces could be easily examined. The cages were kept in a room warmed by hot-water pipes, so that they were under as nearly as possible similar conditions as regards light and heat. The excreta of the monkeys were examined daily, and the general appearance of the animals noted, more especially as regards the condition of the gums. Every few days they were weighed.

We can now proceed to describe the results of the experiments. In

order to study the results of each group more easily they are put together in a tabular form.

*First Group.*—The monkeys fed on boiled rice with 50 grammes of fresh meat and maize daily.

Six monkeys in this group (Table I) were kept under observation.

Table I.—Group 1. Monkeys fed on Boiled Rice, with 50 grammes of Fresh Meat and Maize daily.

No.	Duration of observation.	Weight in kilos.			Diarrhœa commenced.	Blood and mucus in stools.	Gums spongy.
		Original.	Final.	Loss.			
	days.				days.	days.	days.
1	70	2·000	1·450	0·550	62	0	0
2	31	2·250	1·700	0·550	23	0	0
3	28	2·200	1·850	0·350	3	0	0
4	45	2·650	1·950	0·700	7	0	0
5	73	2·750	1·650	1·100	13	0	0
9	39	1·250	1·050	0·200	5	0	0

In the case of No. 5, which lost no less than 1·100 kilos. in seventy-three days, this loss of weight principally occurred during the last seven days, for up to that period this monkey had only lost 300 grammes. During the last seven days, however, severe diarrhœa set in, followed by rapid wasting. The same holds good as regards the other cases. So that although the monkeys on this diet lost weight, possibly from the food not being sufficiently nutritious, the principal loss of weight was apparently due to the diarrhœa.

When we come to consider the diarrhœa, we see that all six monkeys developed this condition sooner or later. As a rule it commenced by being very intermittent, and becoming more severe towards the end, when it speedily proved fatal by the general loss of strength, &c., which it occasioned.

The diarrhœa in monkey No. 1 did not commence until it had been sixty-two days on the diet, when it proved fatal after seven days. In the case of monkey No. 5, on the other hand, it began after thirteen days, but was only slight, and at intervals of three or four days, after which it became very severe; during the last seven days there was rapid wasting, and death occurred on the seventy-third day.

In the case of monkey No. 3, the diarrhœa commenced, however, on the third day, when it was very severe, and afterwards, although the diarrhœa was not so acute and occurred only at intervals, the animal became very feeble, and on the twenty-eighth day was killed by chloroform. At the autopsy no cause for the feeble condition could be

found, although the large intestine was somewhat congested in this case.

In spite of the appearance of this diarrhoea, none of the monkeys in this group showed any signs of either blood or mucus in the motions, the liquid stools being merely of a pale yellowish colour. And in all these cases the gums, although frequently examined, showed no sponginess nor signs of bleeding. The monkeys of this group, as they became emaciated, sat hunched up in their cages, the most usual attitude being with their heads between their knees, as if they were trying to keep themselves warm, although the room was, as already stated, heated by hot-water pipes. They also showed signs of being out of condition by the general roughened condition of their coats.

At the autopsy all these monkeys exhibited more or less marked emaciation, but with the exception of No. 2, which died from pneumonia, in no case was any direct cause of death discoverable. In the bowels were found liquid, light-coloured contents, and only in the case of No. 3 were there any signs of congestion to be noted in the large intestine.

Table II.—Group 2. Monkeys fed on Boiled Rice, with 50 grammes of Tainted Meat and Maize daily.

No.	Duration of observation.	Weight in kilos.			Diarrhoea commenced.	Blood and mucus in stools.	Gums spongy and bleeding.
		Original.	Final.	Loss.			
	days.				days.	days.	days.
6	18	2·000	1·400	0·600	5	0	0
7	14	1·350	1·050	0·300	5	8	13
8	55	1·500	0·950	0·550	17	23	27
10	65	1·600	1·050	0·500	7	28	28
11	54	1·650	1·250	0·400	4	26	27
12	11	2·425	0·150	0·275	6	9	0
13	80	2·050	1·900	0·150	0	0	0
20	62	2·450	1·400	1·050	40	40	40

In the above table (II) the results of eight observations under these conditions are recorded. The monkeys of this group lived from eleven to eighty days, although in the cases of Nos. 8, 10, and 20 we cannot call this the limit of their life, as they were killed in order to examine the influence scurvy, thus artificially produced, would have on their blood.

We see in this Table II that we have the same loss of weight in these monkeys as we had in the six monkeys fed on the fresh meat. In this group the diarrhoea commenced earlier than in those pre-

viously described. In only one case was it delayed forty days; in the other cases it commenced between the fourth and seventh day, except in monkey No. 8, in which it did not commence until the seventeenth day. In these, as in the previous monkeys, diarrhoea, although always occurring, was somewhat intermittent.

Out of those eight monkeys, in no less than six was it seen that the motions were not of the simple diarrhoeaic character of the former group, but contained blood and mucus. In monkeys Nos. 7 and 12 the blood and mucus appeared on the eighth and ninth day respectively, while in the other cases it was more delayed, the diarrhoea having continued for some time previous to its appearance. In some of the cases the motions just before death consisted principally of blood and mucus.

When we turn to the appearance of the gums, we find that in five out of the eight monkeys included in this group they showed sponginess, and in some cases even small ulcers forming. The sponginess of the gums was most marked around the incisors and bicuspid, and, as a rule, did not occur around the molars at all.

The monkeys belonging to this group sat in the same cramped position, with roughened coats, as already described in the previous group. They showed a more marked disinclination to move, or to take interest in objects around them; but in no cases did they show any signs of definite tenderness of their limbs when handled. Only in one case (No. 7) was there any indication of bruising. In this monkey a few days before death two bruises developed on his left knee, about  $\frac{1}{2}$  cm. in diameter, of a dirty red-brown colour, and also sores showed on the sole of the right foot and at the root of the tail.

In all these cases, as in previous monkeys, an autopsy was carried out. In no single instance was there found any signs of hæmorrhage or hæmorrhages into the pleura, pericardium, or peritoneum. The gums in Nos. 8 and 10 were not only spongy, but had a tendency to the formation of ulcers at the root of the incisors.

The stomach and small intestine showed little or no change, while, on the other hand, the large intestine was, in the majority of cases (except Nos. 6 and 13), markedly congested, the congestion being, as a rule, most noticeable at the sigmoid flexure and cæcum. The contents of the small intestine were light yellow, while the large intestine contained more or less bloody mucus.

The only thing else abnormal to be noticed was that in No. 7 the liver was enlarged and fatty, showing markedly the line of the ribs.

We now come to consider the Third Group (Table III). In this the monkeys were fed on boiled rice with 50 grammes of tainted meat and maize daily, but each monkey received, in addition, an apple or a banana.



Table III.—Group 3. Monkeys fed on Boiled Rice, with 50 grammes of Tainted Meat and Maize daily. Each Monkey received a Banana or Apple, these being given on alternate days.

No.	Duration of observation.	Weight in kilos.			Diarrhœa commenced.	Blood and mucus in stools.	Gums spongy and bleeding.
		Original.	Final.	Loss.			
	days.				days.	days.	days.
14	22	1·600	1·350	0·250	16	18	0
15	180	2·200	1·300	0·900	150	0	0
15	13	1·750	1·500	0·250	8	11	11
17	31	2·476	1·500	0·975	9	20	present*
21	123	2·000	1·650	0·350	90	90	0

In this group the animals, therefore, in addition to the rice and maize and tainted meat, received fresh vegetables daily, and may be considered to have been well fed. Five monkeys only were used, and, in spite of the extra food, they all lost weight. In fact, Nos. 15 and 17 lost no less than 900 and 975 grammes of weight in 180 and 31 days respectively. The others, however, did not lose so much weight. In three of the monkeys, Nos. 14, 16, and 17, diarrhœa commenced from eight to sixteen days after the monkeys had been on this diet. But in No. 15 diarrhœa did not commence until the 150th day of observation, and in No. 21 not until the 90th day. In four of the cases blood and mucus appeared in the motions in from eight to eighteen days. When it first occurred in No. 21 was unfortunately not noticed. The other monkey, No. 15, did not show any signs of it. In two of the monkeys, Nos. 16 and 17, spongy gums occurred; in the former, on the eleventh day, while in the latter it was only noted at the autopsy. The other three monkeys showed no signs of bleeding gums.

The autopsy of those monkeys which showed scurvy exhibited, as in those of the second group, marked congestion of the large intestine, with bloody mucus in the contents.

In all the cases there was marked emaciation but no hæmorrhage, either into the pleura, pericardium, or peritoneum.

After this general description of the results obtained in the three groups of experiments, and before discussing their significance, we can consider the changes produced in the blood of animals suffering from the results of scurvy—scurvy being defined by Bristow as “a peculiar form of anæmia arising from a deficiency of vegetable diet, and attended with a tendency to the occurrence of hæmorrhages, profound impairment of nutrition, and great mental and bodily prostration.”

\* Only noted at the autopsy.

*Blood in the Scurvy of Monkeys.*—In order to get monkeys with as well-developed symptoms of scurvy as possible, the animals were kept until not only were they passing bloody mucus by the bowels, but the gums were spongy and easily bled. Unfortunately, the blood of only two monkeys could be examined, as the others died too speedily. The monkeys Nos. 8 and 10 in the second group, however, both showed very well marked symptoms of scurvy, as found in monkeys—diarrhœa, wasting, the motions containing blood and mucus, and the gums spongy and easily bleeding.

Table IV.—Comparing Analysis of Blood of a Normal Monkey with that of two suffering from Scurvy.

	Normal.	Scurvy.	
Weight in kilos.....	2·000	0·950	1·050
Number of corpuscles .....	4,730,000	4,220,000	4,500,000
„ „ leucocytes .....	8125	40,000	—
Hæmoglobin .....	75	48	45
Specific gravity.....	1046	1035	1034
Water .....	83·37	85·18	84·99
Solids .....	16·63	14·82	15·01
Proteids .....	18·27	12·37	15·69
Fibrine .....	0·52	—	0·76
Time of coagulation.....	3 minutes	2 minutes	1 minute
N. ....	2·72	2·31	—
Ash.....	0·75	0·79	—

In the above Table IV the results of the analyses of the blood in the case of these two monkeys are compared with that of a normal monkey, so that we can more readily see the changes produced.

The blood to be examined was collected from the carotid artery while the animal was kept under the influence of ether, and when sufficient blood had been collected for the various analyses, the animal was killed by an overdose of anæsthetic before it returned to consciousness.

*The Number of Red Blood Corpuscles.*—These were estimated by the Thoma-Zeiss' Counter, and in each of these cases the average of two blood counts is given, the result being the number of red blood corpuscles contained in a cubic millimetre of blood.

It is seen that while in the normal monkeys the number of red blood corpuscles is 4,730,000 per cubic millimetre, in the two monkeys suffering from scurvy it is respectively 4,220,000 and 4,500,000.

Other observers have drawn attention to the diminution in the number of red corpuscles in cases of scurvy as quoted by Philip Wales in Ashurst's 'International Encyclopædia of Surgery.'

From these results one may conclude that there is a slight reduction in the number of red blood corpuscles in monkeys fed on tainted meat, although this reduction is nothing like the reduction one finds in the human subject in many of the more severe forms of anæmia.

*The Leucocytes.*—The white blood corpuscles were counted in the same way as the red blood corpuscles. This was carried out on one of the monkeys affected with scurvy. It is seen in the case of the normal monkey that there were 8125 leucocytes per cubic millimetre, while in the case of the monkey suffering from scurvy there were no less than 40,000.

Laboulbène notes the occurrence of an unusual number of white globules in scurvy. We certainly can conclude that there is a very marked leucocytosis produced by the diet of tainted meat.

*The Hæmoglobin.*—The quantity of colouring matter in the blood was estimated by Fleischl's hæmometer. In each case precautions were taken to use the same illumination power, and at least two calculations were made, the average being taken.

It is seen in the above table (IV) that the hæmoglobin present represented 75, while in both the monkeys suffering from scurvy it is very considerably reduced, being 48 and 45 respectively. When we compare this with the small reduction in the number of red blood corpuscles, we see that in the monkeys fed on tainted meat there is produced a very marked hæmoglobinaemia, while at the same time there is probably oligocythæmia.

In fact this condition corresponds with that in the human being in cases of chlorosis, as against those forms of pernicious anæmia or secondary anæmia, where either the red blood corpuscles are reduced out of proportion to the hæmoglobin, or the hæmoglobin and corpuscles are reduced in equal proportions.

*The Specific Gravity of the Blood.*—The estimation of the specific gravity of the blood in these monkeys was carried out by means of the picnometer. In the normal monkey we have a specific gravity of 1046, while in the case of the two monkeys suffering from scurvy we have a specific gravity of 1035 and 1034; so that we can conclude that there is a slight decrease in the specific gravity produced by the diet of tainted meat.

*The Water and Solids of the Blood.*—A given quantity of blood was collected in a platinum crucible and dried to constant weight at 70° C. It is seen that in the normal blood there was 83·37 per cent. of water and 16·63 per cent. solids, while in the case of the monkeys suffering from scurvy the percentage of water was 85·18, with only 14·12 per cent. of solids, in monkey No. 8, while 84·99 per cent. of water, with 15·01 per cent. of solids, occurred in No. 10. It would appear that all observers who have noted the blood in scurvy speak of the marked diminution in the total solids which occurs in this disease. So that we

have with the decrease in the specific gravity of the blood a diminution in the total solids, as one naturally would expect.

*The Proteids of the Blood.*—The total quantity of proteids in the blood was estimated by precipitating a given quantity of blood in 15 volumes of absolute alcohol. After allowing it to stand some days, with frequent stirring, the precipitate was collected on a weighed filter paper, and dried, &c., in the usual manner. By this method it was found that the normal blood contained 18·27 per cent. of proteids, while in the case of the two monkeys fed on tainted meat the quantity of proteids was only 12·37 and 15·69, so that there is a very marked decrease in the quantity of proteids in the blood.

*The Quantity of Fibrine.*—This was estimated by the method of Hoppe-Seyler in one case. It is seen that in the normal monkey there is 0·52 per cent. of fibrine in the blood, while in the case of the monkey suffering from scurvy the fibrine was no less than 0·76, so that we see there was a very marked increase in the quantity of fibrine.

Chalvet, in his analysis of a case of scurvy, comparing it with healthy blood in the normal individual, found the fibrine 0·216, while in the case of scurvy it was 0·434.

Busk, in three well-marked cases of scurvy which occurred in the "Dreadnought" hospital ship, found the fibrine in excess of the normal amount, the least being 0·45 and the greatest 0·65 per cent.

*The Time of Coagulation.*—The time that it took for the blood to coagulate was estimated by Professor Wright's tubes, and it is seen that in the normal monkeys this is three minutes, while in the case of the monkeys suffering from scurvy it was found to be one and two minutes respectively.

The increase in the quantity of fibrine (hyperinosis) with the shortening of the time of coagulation is what one commonly finds in hydræmia in the human subject, and may therefore in all probability be put down to the same cause.

*The Quantity of Nitrogen.*—The total quantity of nitrogen in the blood was estimated by the method of Kjeldahl, and the average of two analyses is given as before. In the normal monkey it is seen that the total nitrogen was 2·72, while in the case of the monkey suffering from scurvy, in which it was analysed, it was 2·31 per cent. There is, therefore, a small decrease in the quantity of nitrogen, this decrease corresponding to the decrease in the quantity of proteids, and as this was only analysed in one monkey, it is as well perhaps not to discuss any theories as to its significance.

*The Ash of the Blood.*—The estimation of the ash was carried out in the ordinary way, but only in the case of one monkey suffering from the effects of tainted meat. It is seen that in the case of the normal monkey the ash was 0·75, while in the case of the monkey fed with tainted meat it was 0·79 per cent.

The average amount in Becquerel's, Rodies's, and Busk's cases of scurvy in the human subject was 0·81, the smallest being 0·55 and the largest 1·15 per cent.

Garrod, in the analysis of the blood in one case of scurvy, found a deficiency of the potassium salts, upon which he formed his well-known theory that scurvy was due to their want.

We therefore see, in reference to this monkey, that the ash does not tend to be decreased with the low specific gravity and diminution of the total solids. It is apparent that the diminution in the total solids is principally due to a lessening in the quantity of proteids.

### *Conclusions.*

The descriptions brought forward in the first part, of several cases of scurvy which occurred in the Arctic regions when the individuals were under the influence of preserved or salted meats, in spite of their taking at the same time either vegetables or lime juice, of the Nares Polar Expedition, in which scurvy occurred, as well as the very striking case of the six priests already mentioned, can be compared on the other hand with conditions of the greatest hardship and privation in the Leigh Smith Expedition, Nansen and Johansen, and the Frederick Jackson land party, as well as in the instance given of the Samoyads who winter on Waigatz and who live on fresh meat; in all of which cases, in spite of the entire absence of vegetables or even lime juice, no scurvy occurred.

If we look at this evidence alone we could almost say we have conclusive experimental evidence that the eating of salted or improperly preserved meat, or tainted meat in any form, can produce scurvy, even when lime juice or vegetables are being taken at the same time.

We have also the support of the fact that bad ventilation, believed by Dr. Neale to be one of the causes of scurvy, was not the cause of scurvy with Dr. Nansen, living on fresh meat and blood—probably owing to the fact that he introduced no ptomaine, and therefore no scurvy occurred.

We now come to consider the experiments on monkeys, and how much or otherwise these experiments confirm the results already given in man. It is necessary to consider what are the symptoms of scurvy. In the present paper it is impossible to go through all the symptoms of scurvy described by the various observers, since different epidemics have shown more markedly various symptoms. We, however, can compare the symptoms in our monkeys with those generally described as accompanying scurvy. The pallor and yellowish colour of the face, which is described as distinctive in scurvy, is of course impossible to be observed in monkeys, although in those monkeys which we consider to suffer from scurvy there was generally a good deal of blue-

ness about the lips and gums. There was a very marked disinclination to bodily movement and a general tendency to mental prostration, for the monkeys took little interest in the things surrounding them, in those cases which showed what we might consider the more definite symptoms of scurvy, such as the bloody mucus and bleeding gums.

At the same time in none of these monkeys did we find any definite tenderness of the limbs, no swelling of the legs, or any purpura. Only in one case do we get the formation of bruise-like sores in an animal which apparently was suffering from scurvy.

In the monkeys included in the first group, which were fed on fresh meat as well as maize and rice, the only symptom we note beyond the wasting is diarrhoea, and none of these monkeys showed anything like the muscular feebleness or general ill-health which was noted in the scorbutic monkeys.

When we compare the second group, Table II, in which the monkeys received the same diet, except that the meat instead of being fresh was tainted, we find a very different state of affairs. These monkeys showed a very much greater prostration, and although it is difficult to judge by the eye they certainly seemed paler and generally out of condition. No less than six out of the eight monkeys thus fed passed blood and mucus in their motions.

The question whether blood and mucus in the motions is to be regarded as one of the symptoms of scurvy, can be easily answered by the fact that, first, Bristow states that "patients suffer from looseness of the bowels, the motions frequently being highly offensive and containing blood." It is also stated by other observers, such as Hilton-Fagge and Osler, as well as in an able article on scurvy in Ashurst's 'International Encyclopædia of Surgery,' by Philip Wales, that the occurrence of hæmorrhages in the mucous membrane of the stomach and bowels is of frequent occurrence.

None of our monkeys vomited, so that whether they suffered from hæmorrhages in the stomach cannot be noted. In the *post mortem* there was no evidence of any such thing.

If this bloody diarrhoea is an evidence of scurvy, we find that no less than six out of the eight monkeys which were given the tainted meat showed this symptom.

We now compare the third group, Table III, in which the monkeys were given fresh fruit, apples or bananas, every day. One can say that the monkeys in this case were well fed. Five monkeys were observed, and out of these five monkeys no less than four developed the symptoms of bloody mucus in their stools, so that in spite of good feeding this symptom of scurvy developed in four out of the five monkeys on full diet.

We come to the next symptom, undoubtedly the most definite sign of scurvy that occurs in man—in fact, it is about the only condition

which is universal in scurvy, and is always found except in those cases in which the teeth are absent—that is, the spongy condition of the gums. When we consider the first group of monkeys which were merely fed on rice, maize, and fresh meat, out of the six monkeys not one showed any appearance of spongy gums, so that we can conclude that in these monkeys none of them showed any scurvy whatever.

We now come to the eight monkeys fed on exactly the same diet, in which the meat was tainted instead of fresh, and here no less than five of the eight monkeys showed sponginess of the gums, and some, not only the sponginess but the gums even ulcerated, so that five out of the eight monkeys showed this sign, which is considered by all who describe scurvy as the most significant.

We now come to those monkeys which were well fed, getting the fresh vegetables every day. Four of these monkeys showed bloody mucus in the stools, and two of them spongy and bleeding gums.

We have further to consider the condition of the blood in the monkeys fed on tainted meat. Scurvy is considered by all authorities to be a peculiar form of anæmia. In two monkeys we had the opportunity of analysing the blood, and it is seen by the analyses that we have marked changes in the blood, a very great diminution in the quantity of hæmoglobin, with a slight diminution in the number of red blood corpuscles—in fact, a condition corresponding to chlorosis, and that is accompanied by leucocytosis.

The specific gravity of the blood is reduced, and this is due to the reduction in the quantity of proteids and not to a marked reduction in the quantity of salines in the blood. The fibrine of the blood is increased, together with an increase in the coagulability of the blood.

When we consider what has been found in the blood of man suffering from scurvy, we find it is universally accepted that there is this condition of anæmia with low specific gravity, the blood being distinctly watery and with a marked excess in the quantity of fibrine. So the condition of the blood of the two monkeys which we have analysed corresponds with that found in the majority of analyses of scorbutic blood.

Considering therefore the occurrence, in the monkeys fed on tainted meat, of bloody mucus in the stools, spongy gums, and characteristic anæmia, we assume that, although the symptom of hæmorrhages into the tissues was not observed, we may fairly conclude that they were really scorbutic.

This conclusion is further justified when we consider, on looking over the description of scurvy given by authors, that all the symptoms except the spongy gums are very often absent in different epidemics.

The fact that the five monkeys fed on tainted meat, in which fresh vegetables were given, showed in a smaller proportion the symptoms of scurvy than the monkeys in the second group, can be sufficiently

explained by the fact that when the monkeys received a banana or an apple every day, they would be less likely to eat as much of the meat as they would otherwise do, and would thus daily receive a smaller dose of ptomaine.

In spite of this fact, in no less than four cases out of the five did we get bloody motions, and in two of the cases spongy gums. In these cases tainted meat alone seems to have produced scorbutic symptoms, although the animals in this group took longer to develop the symptoms, and seemed not to suffer in such a severe form.

Looking at the results of our experiments on monkeys, as a whole, we venture to think that they afford important confirmation of the conclusion derived from Arctic experience, as referred to in the early part of this paper, that the absence or presence of fresh vegetables or lime juice is not alone sufficient for the prevention or the cure of scurvy, and that we must regard the condition of the food in general, and especially the state of preservation of the meat, as the essential factor in the etiology of the disease.

We have to express our thanks to Dr. Francis Goodbody for his untiring assistance in the numerous observations that had to be made during the eighteen months the research was continued.

“The Theory of the Double Gamma Function.” By E. W. BARNES, B.A., Fellow of Trinity College, Cambridge. Communicated by Professor A. R. FORSYTH, Sc.D., F.R.S. Received February 26,—Read March 15, 1900.

(Abstract.)

The memoir deals with a function which is substantially one-quarter of the  $\sigma$  function of Weierstrass, just as the ordinary (simple) gamma function is substantially one-half of the infinite sine product. The analogy between the two functions determines the nomenclature.

In any development of the simple gamma function from the function-theory point of view, it is necessary to use Euler's theorem

$$\lim_{n \rightarrow \infty} \left[ 1 + \frac{1}{2} + \dots + \frac{1}{n} - \log n \right] = \gamma$$

to obtain the product  $\Gamma_1(z/\omega)$  given by

$$\Gamma_1^{-1}(z/\omega) = \omega^{-\frac{z}{\omega}} e^{\frac{\gamma z^2}{\omega}} \cdot z \cdot \prod_{n=1}^{\infty} \left[ \left( 1 + \frac{z}{n\omega} \right) e^{-\frac{z}{n\omega}} \right]$$

as a solution of the difference equation  $f(z+\omega) = zf(z)$ .

Similarly for the elementary theory of the double gamma function